Advances in Technology at the National Renewable Energy Laboratory

Technology Brief

Solar-Heated Fresh Air Cuts Heating Costs

Elegantly Simple System Uses Solar Energy to Preheat Air for Ventilation Systems and to Dry Crops

Take the burden off your shop's heating system. Cut your utility bills by using solar energy to preheat the intake air for your ventilation system—that is what the transpired solar collector does. The collector was recently recognized by *R&D Magazine* as one of the 100 most important technological innovations of the last year and received a 1994 "Best of What's New" award from *Popular Science*. It is the product of the practical initiative of Conserval, a private solar heating and energy conservation company, and the scientific expertise of the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL). The collector preheats fresh outside air by drawing it in through small holes in a dark-colored, south-facing wall. Using this preheated air as the intake for the building's ventilation system provides numerous advantages:

- The transpired solar collector preheats intake air by as much as 30°C (54°F), reducing annual heating costs by $10 to $30 per square meter ($1 to $3 per square foot) of collector wall, depending on the type of fuel used.
- The collector pays for itself within 6 to 7 years for retrofits, or in 3 years or less for new construction, and it is virtually maintenance-free, with no liquids and no moving parts other than the ventilation system fans.
- At night the collector assists heating because heat lost through the main building wall behind the collector system cladding is recaptured.
- Transpired collectors respond to demands for improved indoor air quality, because better ventilation is an integral part of the system.
- Collectors can be added on or designed as part of a building's facade; commercially available Solarwalls© use attractive metal sheeting and are available in many dark colors to enhance building appearance.

Transpired collectors are ideal for industrial and commercial buildings with large ventilation requirements and have proved highly successful on major manufacturing plants. But they are applicable wherever outside air must be heated, and installations have included a school and corridor ventilation for high-rise apartments. The collector can also preheat combustion air for central-heating plants or industrial furnaces. Several systems are already being used for crop drying—a use that could prove to be of tremendous benefit for less-developed countries.

Photo to come later.

Warren Gretz, NREL

NREL researchers hold a transpired solar collector panel showing the holes that make the preheating system so effective.

Simple Concept

A transpired solar collector system uses a wall of dark perforated sheeting (similar to conventional siding, but mounted several inches from the main wall). An additional fan may be required as part of the system, or the building's own ventilation fans may be sufficient. As discussed below, no glazing (cover glass) is needed. The sheeting may be installed on any south, southeast, or southwest-facing wall of any building. The dark wall absorbs solar radiation and heats fresh air drawn through its perforations into a plenum—a space between the metal and the main building wall. Heat escaping through the main building wall is also captured in this plenum. The force of the fans that pulls the outside air in through the perforations—heating it in the process—also draws it up the plenum and into the building's ventilation system for additional conventional heating, if needed.

Photo to come later.

Warren Gretz, NREL

NREL researchers used this wind tunnel setup to test various perforation configurations and to investigate boundary-layer effects.

On a sunny day, the system can preheat air by 17° to 30°C (30° to 54°F). Even on cloudy days, the system helps because it also absorbs diffuse light—about 25% of annual solar radiation. In the winter, snow cover on the ground helps reflect even more radiant energy to the wall.

Sophisticated Refinements

The effectiveness of the transpired collector is the result of parallel efforts

The Science Behind the System

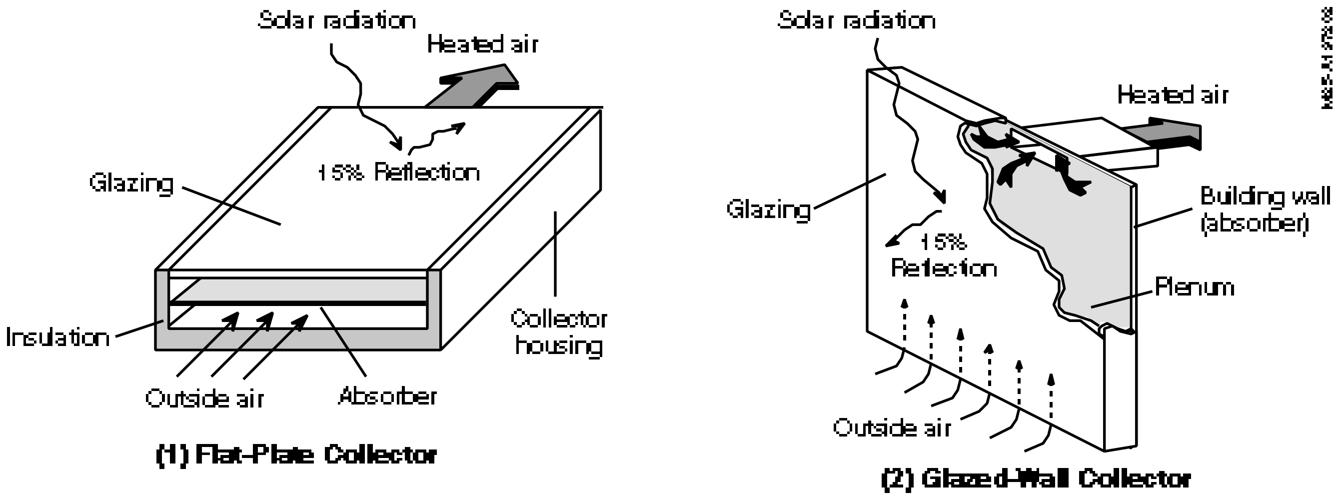
Part of the beauty of transpired solar collector systems is how intuitively logical and easily understood the basic concept is: the sun heats the surface of a wall; the wall heats the adjacent outside air; the warm air is drawn through holes in the wall by the building ventilation system. But understanding exactly how it works—to achieve optimal efficiency—gets more difficult. How do you maintain uniform air flow? How many holes should there be? And how big, how far apart, and in what kind of pattern should the holes be? To answer these and other questions and to develop a computer model, NREL researchers delved deep into the theories of fluid dynamics and heat transfer.

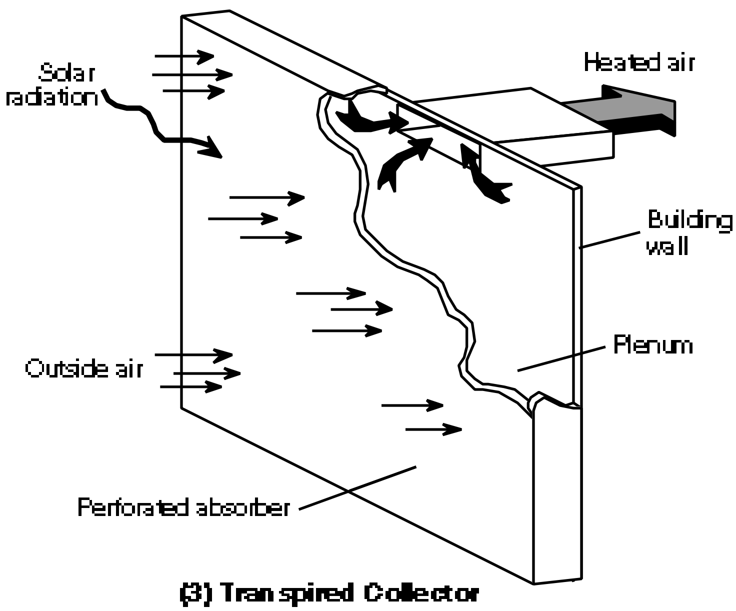
Previous relevant research on flow past porous surfaces had been done almost entirely with regard to drag on airplane wings or injection cooling for turbine blades or rocket nozzles. To apply the theory to transpired heating required charting new territory. The central issue of the research was determining and maximizing the amount of heat picked up by the air as it passed through the holes. Other important research issues included flow distribution and pressure drop considerations.

One of the most interesting results of the researchers' theoretical work was actually counterintuitive. They disproved a concern about the concept that had initially made them wary. One might expect that strong winds blowing along a solar collection wall would carry away much of the heat absorbed. In fact, boundary-layer theory showed that for transpired collectors, there is only a very thin layer of heated air next to the absorber; that most of that heat gets pulled through the holes; and that rather than carrying away heat, the wind enhances heating by pushing air along the collector.

To test the theory and develop the necessary coefficients to complete their computer model, the researchers used wind tunnel testing, infrared thermography, computer simulations, and trials on installed systems. They have now adapted the model to form the basis of a personal computer program that designs optimal systems for particular installations.

Evolution of Solar Ventilation Preheating





Previous efforts to use solar energy to preheat outside air for ventilation used technologies developed for heating indoor air. The earliest systems used conventional flat-plate solar collectors (1). To reduce costs, later systems used the building wall as the solar absorber with outside air passing between it and an insulating layer of glazing (2). Specifically designed to heat outside air, the transpired collector takes a radical new approach (3). It efficiently heats and captures fresh air by drawing it through a perforated absorber, eliminating the cost and the reflection losses associated with a glazing.

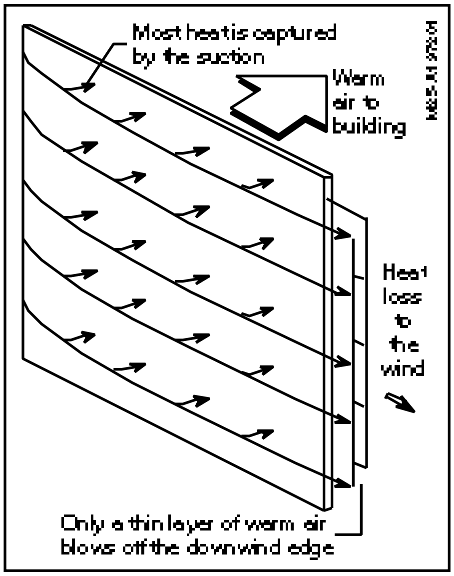
by NREL and Conserval. NREL scientists researching solar heating and air flow for unglazed, transpired collectors discovered that Conserval was already testing Solarwall© collector systems employing the same principle. Spurred by practical problems with previous products that used glazing—glass or other transparent material—to hold in heat absorbed by a black-surfaced back wall, Conserval developed an unglazed, transpired (perforated) system able to capture 60% to 65% of the solar radiation striking it.

The NREL researchers investigated the size and spacing of perforations, the depth of the plenum, and the shape of the header (an optional air collection duct at the top of the collector wall) using wind tunnel tests, infrared thermography, computer modeling, and full-scale outdoor test facilities. They then suggested refinements to Conserval, which resulted in improved transpired collector systems that can capture up to 80% of the available solar energy. They also showed that the absorber did not have to be metal.

Transpiration Holes Key to Effectiveness

The transpired solar collector is more efficient, less expensive, and better suited to ventilation preheating than previous solar air collectors, which generally relied on glazing to hold in absorbed heat. Because most glazings reflect approximately 15% of incident radiation, eliminating them makes a major efficiency contribution.

Eliminating glazing and the insulation needed for flat-plate collectors also substantially reduces material costs.



Boundary layer theory showed the transpired solar collector loses little heat to the wind.

Photo to come later.

Courtesy of Conserval

This 365-m^2 (3930-ft^2) Solarwall© on the General Motors Battery Plant in Oshawa, Ontario, has successfully preheated ventilation air for the plant since 1991, averaging 65% conversion efficiency. Newer designs can achieve up to 80% efficiency.

Using metal sheeting as the solar heat absorber and integrating it with the building wall simplifies installation. As a result, transpired solar collectors cost half as much as glazed, flat-plate collectors.

Demands for better indoor air quality are increasing the ventilation needs of many buildings. Because air delivery systems used in conjunction with transpired solar collection increase air mixing, improved air quality is an added benefit of reducing energy costs.

Worldwide Potential

Space heating is a universal need in cold climates, as well as a major user of energy—some 13% of U.S. energy is used for heating residential and commercial buildings alone. By reducing this energy use, transpired solar collectors can also reduce building operation costs, reliance on imported fossil fuels, pollution, and greenhouse gas generation.

In warm climates, crop drying and other possible transpired solar collector uses also have tremendous potential. Because of the lack of refrigerated storage, less-developed economies in Latin America and throughout the world rely extensively on crop drying. To avoid expensive energy costs, both domestic produce and export crops such as coffee and tea are dried by laying them out in the sun. But as much as one-third of these crops can be lost to rain or insects. By allowing crops to be dried indoors, transpired solar collector systems could prevent these losses and dramatically improve productivity.

Recognized by the DOE Energy-Related Inventions Program as being among the top 2% of energy inventions and by the prestigious R&D 100 award, transpired solar collector systems are easily incorporated into standard commercial building ventilation systems. They pay for themselves quickly and produce substantial environmental and economic benefits with no negative side effects.

For More Information

General Information and other NREL Technology Briefs:
Technical Inquiry Service
(303) 275-4099

Technical Information on this NREL Project:
Charles Kutscher
(303) 275-6024

Craig Christensen
(303) 275-6022

Product and System Engineering Information:
John Hollick, Conserval Engineering, Inc.
(416) 661-7057

Richard Grainger, Conserval Systems, Inc. (U.S. sales)
(716) 835-4903

NREL Business Information:
Technology Transfer Office
(303) 275-3008

The National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401-3393, is a national laboratory of the U.S. Department of Energy (DOE), managed for DOE by Midwest Research Institute

Produced by the Communications and MIS Branch for the Technology Transfer Office
NREL/MK-336-6702 Revised 12/94